ENGLISH TRANSLATION OF INTERNATIONAL APPLICATION AS FILED

DESCRIPTION

DISCHARGE ELECTRODE CLAD MATERIAL AND DISCHARGE ELECTRODE

TECHNICAL FIELD

[0001] The present invention relates to a discharge electrode for a fluorescent discharge tube to be used, for example, as a back light of a liquid crystal display, and an electrode material for the discharge electrode.

BACKGROUND ART

[0002] A small size fluorescent discharge tube is used as a back light for a liquid crystal device. As shown in Fig. 7, the fluorescent discharge tube includes a glass tube 51 having a fluorescent film (not shown) provided on an interior surface thereof and containing a discharge gas (a mercury vapor and a noble gas such as argon gas) confined therein, and a pair of discharge electrodes 52 provided as cold cathodes on opposite ends of the glass tube 51. The discharge electrodes 52 each have a cup shape, including a tubular portion 53 having an open end and an end plate portion 54 formed unitarily with the tubular portion 53 to close the other end of the tubular portion 53. A stem-like support conductor 55 is hermetically arranged through an end portion of the glass tube 51 with one end

thereof welded to the end plate portion 54 and with the other end thereof connected to a lead wire 57. The support conductor 55 is generally composed of W (tungsten), and typically laser-welded to the discharge electrode 52 in the air.

[0003] The discharge electrode 52 is conventionally composed of pure Ni, and has an inner diameter of about 1.5mm, a length of about 5mm and a wall thickness of the tubular portion 53 of about 0.1mm, for example, for the small fluorescent discharge tube to be used as the back light. The discharge electrode is typically formed unitarily from a pure Ni thin plate having the same thickness as the tubular portion by deep drawing.

[0004] The pure Ni, which is a stable material excellent in formability, is used for the formation of the discharge electrodes for the fluorescent discharge tube as described above, but the fluorescent discharge tube with discharge electrodes made of pure Ni is disadvantageous in a relatively short service life. That is, when the fluorescent discharge tube turns on a light, a sputtering phenomenon occurs in which the electrodes are bombarded with ions and the like to release atoms of the electrode metal. Thus, the electrode metal is worn by the sputtering. Further, the released electrode metal atoms are combined with mercury contained in the glass tube, so that the mercury vapor in

the glass tube is consumed. Conventionally, Ni of the electrode metal is more liable to release atoms by the sputtering or has a higher sputtering rate. Hence the consumption of mercury is increased, so that the service life of the discharge tube is deteriorated.

[0005] Therefore, an attempt has recently been made to use a metal selected from Nb (niobium), Ti (titanium) and Ta (tantalum) and alloys of these metals each having a lower sputtering rate for the formation of the discharge electrodes as stated in JP 2002-110085-A (Patent Document 1).

Patent Document 1: Japanese Unexamined Patent Publication No. 2002-110085

DISCLOSURE OF THE INVENTION

Problems to be solved by the invention

[0006] However, Ti is liable to absorb the discharge gas contained in the fluorescent discharge tube and, hence, is not suitable as the electrode material. Further, Ta is a very expensive metal material and, hence, is not suitable for mass production. Nb is free from these disadvantages, but more expensive than Ni. Further, Nb has a high melting point (2793°C), requiring a high welding temperature when a support conductor of W which also has a high melting point (3653°C) is welded to a Nb discharge electrode. Therefore, a relatively tight oxide film is

liable to be formed on a welded portion. Where the discharge electrodes to which the support conductors are respectively welded are sealed in the glass tube with the oxide film left adhering on the discharge electrodes, the fluorescent film formed on the interior surface of the tube is liable to react with oxygen occurred due to decomposition of the oxide film during electric discharge and thereby the fluorescent film is deteriorated. Therefore, the step of removing the oxide film formed on the electrode surface is required after the welding of the support conductor.

[0007] In view of the foregoing, it is an object of the present invention to provide a discharge electrode material which enables to form a discharge electrode having a service life and discharge characteristics equivalent to those of a discharge electrode composed of pure Nb or a Nb alloy mainly composed of Nb and having excellent weldability to a support conductor to do without the oxide film removing step after the welding and which enables to reduce material costs, and to provide a discharge electrode produced from the discharge electrode material.

Means for solving the problems

[0008] The inventors of the present invention carefully observed the wear of a Nb discharge electrode after a lapse of a service life of a fluorescent discharge tube, and found that an interior bottom portion of the cup-shaped discharge

electrode was selectively worn to a depth of about 10μm to about 20μm. This taught the inventors that inner surface portions of an end plate portion and a tubular portion of the cup-shaped discharge electrode each having a thickness of at least about 20μm should be composed of Nb but outer portions of the end plate portion and the tubular portion may be composed of an oxidation resistant metal material having good weldability. The present invention has been accomplished on the basis of such teachings.

[0009] A discharge electrode clad material according to one aspect of the present invention comprises a base layer composed of pure Ni or a Ni-based alloy mainly comprising Ni, and a surface layer bonded to the base layer and composed of pure Nb or a Nb-based alloy mainly comprising Nb, the surface layer having a thickness of not smaller than 20μm and not greater than 100μm.

In this double layer clad material, only the surface layer is composed of the pure Nb or the Nb-based alloy (hereinafter referred to simply as "Nb" when the pure Nb and the Nb-based alloy are not distinguished from each other). A cup-shaped discharge electrode is produced from the clad material with an inner surface portion thereof defined by the surface layer of the clad material, whereby only the inner surface portion virtually contributable to discharge is composed of Nb. Thus, material costs can be reduced.

In addition, the discharge electrode has a service life equivalent to that of a discharge electrode entirely composed only of pure Nb or a Nb-based alloy mainly composed of Nb, because the surface layer has a thickness of not smaller than 20μm and not greater than 100μm. Since the base layer is composed of the pure Ni or the Ni-based alloy (hereinafter referred to simply as "Ni" when the pure Ni and the Ni-based alloy are not distinguished from each other), the clad material is excellent in oxidation resistance and weldability to a support conductor. This makes it possible to do without the oxide film removing step, thereby reducing production costs.

[0010] The base layer of the clad material may be composed of a stainless steel as well as Ni. The stainless steel is highly resistant to oxidation, and very excellent in bondability to Nb. Since an outer portion of the discharge electrode is not virtually contributable to the discharge, the base layer of the stainless steel hardly influences discharge characteristics. Further, the material costs can be reduced as compared with a case in which the base layer is composed of Ni.

[0011] A clad material according to another aspect of the present invention comprises a base layer composed of pure Ni or a Ni-based alloy mainly comprising Ni, an intermediate layer bonded to the base layer and composed of a ferrous

material, and a surface layer bonded to the intermediate layer and composed of pure Nb or a Nb-based alloy mainly comprising Nb, the surface layer having a thickness of not smaller than 20μm and not greater than 100μm.

In this triple layer clad material, the bondability between the intermediate layer and the base layer and between the intermediate layer and the surface layer is very excellent, so that the bondability of the surface layer is improved. In addition, the use amount of the pure Ni or the Ni-based alloy can be reduced. Since front and rear surfaces of the intermediate layer are respectively covered with the surface layer and the base layer, so that the intermediate layer hardly needs oxidation resistance, the intermediate layer may be composed of the ferrous material. The intermediate layer is preferably composed of a stainless steel, because a press-formed stainless steel product has a high strength.

[0012] The base layer may be composed of a Ni-based alloy consisting of 1.0 to 12.0 mass% of one or both of Nb and Ta, and the balance of Ni and inevitable impurities. The addition of the predetermined amount of Nb and Ta improves the corrosion resistance of the base layer to mercury vapor, thereby improving the durability of the discharge electrode.

[0013] In the double layer clad material, the base layer

may have a strip-like shape, and the surface layer may comprise at least one elongated surface layer bonded onto a widthwise middle portion of the base layer between widthwise opposite edge portions of the base layer as extending longitudinally of the base layer. In the triple layer clad material, the intermediate layer may have a strip-like shape, and the base layer and the surface layer may respectively comprise at least one elongated base layer and at least one elongated surface layer provided between widthwise opposite edge portions of the intermediate layer as extending longitudinally of the intermediate layer.

Where the surface layer is disposed on the widthwise middle portion of the elongated base layer of the double layer clad material or the base layer and the surface layer are respectively disposed on widthwise middle portions of the elongated intermediate layer of the triple layer clad material, opposite edge portions of the clad material can be utilized as plate press margins or feed margins in a press-forming process. Since the bonding area of the surface layer (of the double layer clad material) or the bonding areas of the surface layer and the base layer (of the triple layer clad material) are reduced, the use amounts of Nb and Ni can be further reduced.

[0014] In the double layer clad material, the surface layer preferably has a thickness which is not greater than 70%

of the total thickness of the base layer and the surface layer. In the triple layer clad material, the surface layer preferably has a thickness which is not greater than 70% of the total thickness of the base layer, the intermediate layer and the surface layer.

The pure Nb and the Nb-based alloy each have a great yield elongation. Therefore, when a Nb plate material is formed into a cup shape by deep drawing, Luders bands are formed in a tubular wall of the cup, so that the interior surface of the tubular wall is liable to be undulated. Where the tubular wall has undulations, a forming punch is liable to bite into projections of the undulations in the deep drawing process, thereby deteriorating the press formability. In the significant case, this makes it impossible to perform the forming operation. On the contrary, the base layer bonded onto the Nb surface layer (of the double layer clad material) or the base layer and the intermediate layer bonded onto the Nb surface layer (of the triple layer clad material) serve as a back-up layer for the surface layer, whereby deformation of the surface layer is suppressed to prevent the undulations of the surface layer which may otherwise occur due to the Luders bands. Therefore, excellent press formability can be ensured. If the thickness of the surface layer is greater than 70% of the total thickness, it is difficult to suppress the

occurrence of the undulations even with the provision of the back-up layer, thereby deteriorating the press formability. Therefore, the thickness of the surface layer is preferably not greater than 70%, more preferably not greater than 60%, of the total thickness.

[0015] A discharge electrode according to the present invention comprises a tubular portion having an open end, and an end plate portion formed integrally with the tubular portion to close the other end of the tubular portion, and is unitarily produced from the aforesaid double layer or triple layer clad material by press forming with inner surfaces of the tubular portion and the end plate portion defined by the surface layer of the double layer or triple layer clad material.

Since the discharge electrode is produced by the press forming, the productivity is excellent. Further, only a portion of the discharge electrode virtually contributable to the discharge is composed of Nb, so that the material costs can be reduced without needlessly using Nb for formation of the other portion of the discharge electrode not contributable to the discharge. In addition, the discharge electrode has excellent weldability to a support conductor, and does not require the oxide film removing step after the support conductor is welded to the discharge electrode.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] Fig. 1 is a sectional view illustrating a major portion of a discharge electrode clad material according to a first embodiment of the present invention;

Fig. 2 is a cross sectional view of a discharge electrode clad material according to a variation of the first embodiment;

Fig. 3 is a sectional view illustrating a major portion of a discharge electrode clad material according to a second embodiment of the present invention;

Fig. 4 is a cross sectional view of a discharge electrode clad material according to a variation of the second embodiment;

Fig. 5 is a longitudinal sectional view of a discharge electrode for a fluorescent discharge tube according to the first embodiment of the present invention;

Fig. 6 is a longitudinal sectional view of a fluorescent discharge tube according to the second embodiment of the present invention; and

Fig. 7 is a sectional view illustrating a major portion of a fluorescent discharge tube including a conventional discharge electrode.

DESCRIPTION OF REFERENCE CHARACTERS

[0017] 1, 11 Base layer

2, 12 Surface layer

13 Intermediate layer

21 Tubular portion

22 End plate portion

BEST MODE FOR CARRYING OUT THE INVENTION

[0018] Fig. 1 is a sectional view of a discharge electrode double layer clad material according to a first embodiment of the present invention. The clad material includes a base layer 1 of pure Ni, a Ni-based alloy mainly containing Ni or a stainless steel, and a surface layer 2 of pure Nb or a Nb-based alloy mainly containing Nb. The surface layer 2 is bonded to the base layer 1 by roll pressure bonding and diffusion bonding. The pure Ni, the Ni-based alloy and the stainless steel are excellent in oxidation resistance, cold workability and deep drawability.

[0019] The Ni-based alloy preferably contains Ni in a proportion of not smaller than 80 mass%, more preferably not smaller than 85 mass%. The Nb-based alloy preferably contains Nb in a proportion of not smaller than 90 mass%, more preferably not smaller than 95 mass%. Usable as the Ni-based alloy are an Ni-Nb alloy, a Ni-Ta alloy, and a Ni-Nb-Ta alloy, which consist of 1.0 to 12.0 mass% of one or both of Nb and Ta and the balance of Ni and inevitable impurities. The addition of the aforesaid amount of Nb and Ta does not adversely influence the formability, and is effective for improvement of corrosion resistance to

mercury vapor, so that the durability of the resulting electrode is improved. Further, a Ni-W alloy, which consists of 2.0 to 10 mass% of W and the balance of Ni, is usable as the Ni-based alloy. Like Nb and Ta, W also improves the corrosion resistance to the mercury vapor. In combination with Nb and/or Ta, W may be added to the Ni-based alloy but, in this case, a W content is preferably not greater than about 6.0%.

[0020] Usable as the stainless steel are various stainless steels including austenite stainless steels such as SUS304 and ferrite stainless steels such as SUS430. These stainless steels are more excellent in corrosion resistance, oxidation resistance and formability than the pure Ni and the Ni-based alloy, and have excellent diffusion-bondability to the surface layer. Particularly, the austenite stainless steels are preferred because of their excellent cold workability and their high strength after the forming.

[0021] The surface layer 2 composed of the pure Nb or the Nb-based alloy is required to have a thickness of at least 20μm in consideration of the wear of the discharge electrode, and preferably has a thickness of about 20μm to about 100μm, preferably about 40μm to about 80μm, in consideration of safety and thickness balance between the surface layer 2 and the other layer or the entire clad material. On the

other hand, the clad material is required to have a thickness of about 0.1mm to about 0.2mm from the viewpoint of the deep drawability. Therefore, the thickness of the base layer 1 may be properly determined in consideration of the thickness of the surface layer 2 so as to come to the thickness of the clad material. From the viewpoint of the weldability of the discharge electrode to a support electrode, it is sufficient that the base layer 1 has a thickness of about 20μm to about 50μm. The thickness of the surface layer 2 is preferably not greater than 70%, more preferably not greater than 60%, of the total thickness of the surface layer 2 and the base layer 1 in order to ensure that the base layer 1 serves as the backup layer for prevention of deformation of the surface layer 2 and the clad material obtains a good press formability in a deep drawing process.

[0022] The surface layer 2 may be bonded onto the entire surface of the base layer 1 as shown in Fig. 1. Alternatively, as shown in Fig. 2, the clad material may be provided as a partial clad material in which the base layer 1 has a strip-like shape and an elongated surface layer 2 of Nb is bonded onto a middle portion of the base layer 1 except widthwise opposite edge portions of the base layer 1. Although the partial clad material is illustrated as having a single surface layer 2 in Fig. 2, a plurality of elongated surface layers may be arranged on the base

layer as each extending longitudinally of the base layer.

[0023] Where cup-shaped discharge electrodes are continuously formed by utilizing the strip-like clad material, the opposite edge portions of the strip-like clad material serve as guide margins for feeding the clad material to a press and as plate press margins in the press forming process, and the middle portion of the clad material is continuously press-formed into cup-shaped discharge electrodes. After the forming process, the opposite edge portions are discarded. Therefore, it is not necessary to cover the opposite edge portions with an expensive Nb layer, but it is sufficient to provide the surface layer only on the middle portion of the base layer as in the partial clad material. Thus, the clad material provided in the form of the partial clad material makes material costs further reduced. More specifically, where cup-shaped discharge electrodes each having an outer diameter of about 1.7mm and a length of about 5mm are continuously formed by deep drawing, the middle portion of the clad material (with the single surface layer) to be used for the formation of the discharge electrodes has a width of about 8mm, and the opposite edge portions each have a width of about 2mm.

[0024] Fig. 3 is a sectional view of a discharge electrode triple layer clad material according to a second embodiment of the present invention. The clad material includes a

base layer 11 composed of pure Ni or a Ni-based alloy, an intermediate layer 13 composed of a ferrous material, and a surface layer 12 composed of pure Nb or a Nb-based alloy. The base layer 11, the intermediate layer 13 and the surface layer 12 are pressure-bonded by rolling and diffusion-bonded to one another. Usable as the ferrous material of iron and steel are pure iron, a mild steel and a stainless steel. Any of various stainless steels may be used as the stainless steel, but an austenite stainless steel is preferred because of its high strength after the forming.

[0025] The base layer 11 and the intermediate layer 13 of this embodiment correspond to the base layer 1 of the first embodiment. In this embodiment, the material costs can be reduced as compared with the case where the base layer 1 is entirely composed of the pure Ni or the Ni-based alloy. In addition, the diffusion bondability between the intermediate layer 13 and the base layer 11 and between the intermediate layer 13 and the surface layer 12 is very excellent.

[0026] As in the first embodiment, the triple layer clad material commonly has a thickness of about 0.1mm to about 0.2mm. The base layer 11 preferably has a thickness of about 20μm to about 50μm for ensuring weldability to the support conductor. The surface layer 12 has a thickness

of about 20μm to about 100μm as described above.

[0027] Like the double layer clad material, the triple layer clad material may be provided as a partial clad material as shown in Fig. 4. That is, the triple layer clad material may have a construction such that the intermediate layer 13 has a strip-like shape, and the base layer 11 and the surface layer 12 are bonded onto middle portions of the intermediate layer 13 of the clad material which are contributable to the formation of the cup-shaped discharge electrode.

[0028] Figs. 5 and 6 illustrate cup-shaped discharge electrodes (bottomed tubular discharge electrodes) which are produced from the double layer clad material according to the first embodiment and the triple layer clad material according to the second embodiment, respectively, by deep drawing. These discharge electrodes each include a tubular portion 21 having an open end and an end plate portion 22 formed unitarily with the tubular portion 21 to close the other end of the tubular portion 21, and each have an interior surface portion defined by the surface layer 2, 12 of the clad materials. When such a discharge electrode is used, a bottom interior surface portion of the discharge electrode is liable to be worn by discharge. Since the interior surface portion of the discharge electrode is defined by the surface layer 2, 12 of Nb, the discharge electrode has

discharge characteristics and a service life equivalent to those of a discharge electrode composed of Nb alone when used in a fluorescent discharge tube, and the use amount of Nb is reduced. In addition, a support conductor can be easily welded to the discharge electrode by the provision of the base layer 1, 11.

[0029] For the production of the cup-shaped discharge electrode, a disk-shaped blank material is prepared by stamping the double layer or triple layer clad material, and then deep-drawn by press forming. The blank material may be stamped out with a part thereof being connected to an outer periphery of the clad material via a connection portion. In this case, the cup-shaped discharge electrode is disconnected from the connection portion after the deep drawing.

[0030] A clad material production method will hereinafter be described.

To produce the double layer clad material, a Ni sheet as a material for the base layer 1 and a Nb sheet as a material for the surface layer 2 are stacked and pressure-bonded by rolling. That is, the Ni sheet and the Nb sheet thus stacked are cold-rolled through a pair of rolls to be pressure-bonded. To produce the triple layer clad material, a Ni sheet as a material for the base layer and a Nb sheet as a material for the surface layer are stacked on opposite

surfaces of a ferrous material sheet as a material for the intermediate layer, and pressure-bonded together by rolling. A rolling reduction for the pressure bonding is commonly about 50% to about 70%. The pressure-bonded sheets are maintained at a temperature of about 900°C to about 1100°C for several minutes for diffusion annealing. Since Nb is liable to react with N_2 and H_2, the diffusion annealing is preferably performed in the atmosphere of an inert gas (e.g., a noble gas) such as argon or in vacuum. Further, finishing cold rolling may follow the diffusion annealing, as required, for adjustment of the thickness of the clad material. After the finishing rolling, annealing may be performed under the same conditions as in the aforesaid diffusion annealing, as required, for softening the material.

[0031] The clad material thus produced is slit into elongated strips each having a proper width as required, and blank materials are stamped out of the elongated strips. Then, the blank materials are each press-formed. For preparation of the partial clad material shown in Fig. 2 or 4, the material sheets are preliminarily slit into elongated strips each having a desired width, and then the strips are subjected to pressure bonding by rolling, diffusion annealing and finishing rolling.

[0032] The present invention will be described more

specifically by way of examples thereof. However, it should be understood that the invention be not limited to the examples.

Examples 1

[0033] Double layer clad material samples each including a base layer of pure Ni or a stainless steel (SUS304) and a surface layer of pure Nb diffusion-bonded to each other were prepared in the following manner.

A pure Ni sheet and a stainless steel sheet (each having a width of 30mm, a length of 100mm and a thickness of 1.0mm) were prepared as materials for the base layer, and a pure Nb sheet having the same width and length as those sheets (and a thickness of 0.5mm) was prepared as a material for the surface layer. The pure Ni sheet or the stainless steel sheet and the pure Nb sheet were sacked and pressure-bonded by cold rolling. Thus, a double layer pressure-bonded sheet having a thickness of 0.6mm was provided. The double layer press sheet was maintained at 1050°C in an argon gas atmosphere for three minutes for diffusion annealing, whereby a primary clad material was provided. After the annealing, the primary clad material was cold-rolled at a rolling reduction of 75%, and then annealed under the same conditions as in the previous annealing, whereby a secondary clad material was provided. The base layer and the surface layer of the secondary clad

material respectively had average thicknesses of 0.1mm and 0.05mm.

[0034] A triple layer clad material sample including a base layer of pure Ni, an intermediate layer of a stainless steel (SUS304) and a surface layer of pure Nb diffusion-bonded to one another in this order was prepared in the following manner.

A pure Ni sheet having a width of 30mm, a length of 100mm (and a thickness of 0.8mm) were prepared as a material for the base layer, and a stainless steel sheet having the same width and length as the pure Ni sheet (and a thickness of 0.8mm) was prepared as a material for the intermediate layer. Further, a pure Nb sheet having the same width and length as those sheets (and a thickness of 0.8mm) was prepared as a material for the surface layer. The pure Ni sheet, the stainless steel sheet and the pure Nb sheet were sacked and pressure-bonded by cold rolling. Thus, a triple layer pressure-bonded sheet having a thickness of 0.75mm was provided. The triple layer pressure-bonded sheet was diffusion-annealed under the same conditions as described above, whereby a primary clad material was provided. After the annealing, the primary clad material was cold-rolled at a rolling reduction of 80%, and then annealed under the same conditions as in the previous annealing, whereby a secondary clad material was

provided. The layers of the secondary clad material each have an average thickness of 0.05mm.

For comparison, a pure Ni thin plate, a pure Nb thin plate and a pure Mo thin plate (which are collectively referred to as "pure metal thin plates") each having a thickness of 0.15mm were prepared. These thin plates were prepared by cold rolling and then subjected to annealing at 1050°C in an argon gas atmosphere for three minutes.

[0035] By utilizing the double layer secondary clad materials, the triple layer secondary clad material and the pure metal thin plates, cup-shaped discharge electrodes each having an outer diameter of 1.7mm, an inner diameter of 1.5mm and a tube length of 5mm as shown in Figs. 5 and 6 were produced through a deep drawing process including eight drawing steps without intermediate annealing. None of these samples suffered from cracking and like problems in the deep drawing process. The discharge electrodes produced from the clad materials were each observed in section taken along the thickness of the tubular portion thereof, but no crack was found in the interfaces of the respective layers.

[0036] On the other hand, a support conductor composed of pure W and having an outer diameter of 0.8mm and a length of 2.8mm was prepared as a welding counterpart. The support electrode was butt-welded to (or welded in abutment against)

a center portion of an outer surface of an end plate portion 22 of each of the cup-shaped discharge electrodes. The welding was performed under the following conditions, which were equivalent to optimum conditions to be employed for welding the support conductor of W to a discharge electrode entirely composed of pure Ni.

(1) Welding machine herein used

Butt welding machine: IS-120B available from Miyachi Technos

Transformer: IT-540 (having a winding ratio of 32)

(2) Welding conditions

Voltage: 0.5V to 1.0V

Current: 300A to 800A

[0037] The welding strength of a portion of the cup-shaped discharge electrode welded to the support electrode was measured in the following manner. The discharge electrode and the support conductor were held by clamps and pulled in opposite directions by a tensile tester. A maximum tensile strength observed when the support conductor was disconnected from the discharge electrode was determined as the welding strength. In practice, it is sufficient that the welding strength is not smaller than 100N.

[0038] A sputtering test piece (10mm×10mm) was sampled from each of the clad materials and the pure metal thin plates, and a sputtering rate was measured in the following manner.

First, a test surface of the sampled test piece was polished to be mirror-finished. In an ion beam apparatus (Model VE-747 available from Veeco), the test piece was used as a target, and a voltage of 500V was applied between the target and a substrate and then argon ions (1.3×10^{-6} Torr) were accelerated to impinge on the test surface for a predetermined period (120min) for sputtering. A part of the mirror-finished test surface was masked to define a non-sputtering portion. After the sputtering, a step was formed on a boundary between a portion of the mirror-finished surface of the test piece partly worn by the sputtering and the masked non-sputtering portion. The step was measured by a contact roughness meter (Model DEKTAK2A available from Sloan), and the sputtering rate (Å /min) was determined from the following expression:

Sputtering rate=Step(Å)/Sputtering period (120min)

The welding strength and the sputtering rate thus determined are shown in Table 1.

[0039] Table 1

Sample No.	Structure of sample	Welding strength (N)	Sputtering rate Å /min	Remarks
1	Pure Ni thin plate	130	242	Comparative example
2	Pure Nb thin plate	(Unable to weld)	117	Comparative example
3	Pure Mo thin plate	(Unable to weld)	171	Comparative example
4	Ni/Nb clad material	130	117	Inventive example
5	Ni/SUS/Nb clad material	130	117	Inventive example
6	SUS/Nb clad material	130	117	Inventive example

[0040] As can be understood from Table 1, the clad materials of Samples No. 4, No. 5 and No. 6 (Inventive Examples) each had excellent deep drawability, sufficient weldability with a welding strength of not smaller than 100N, and a sputtering rate equivalent to that of pure Nb.

On the other hand, the pure Ni material of Sample No. 1 (Comparative Example) had sufficient weldability, but was poor in durability with a higher sputtering rate. The pure Nb material and the pure Mo material of Samples

No. 2 and No. 3 (Comparative Examples) were poor in weldability, because these materials each had a high melting point and the welding under the aforesaid welding conditions was impossible. Further, the pure Mo material had a high sputtering rate and was easily worn by the sputtering regardless of a high melting point.

Examples 2

[0041] Double layer clad materials each including a base layer of pure Ni (Ni layer) and a surface layer of pure Nb or pure Mo (Nb layer or Mo layer) bonded to each other were prepared in the following manner.

Ni sheets having a width of 30mm, a length of 100mm and different thicknesses were prepared as materials for the base layer, and pure Nb sheets and pure Mo sheets having the same width and length as the Ni sheets and different thicknesses were prepared as materials for the surface layer. The Ni sheets and the pure Nb sheets or the pure Mo sheets were sacked as making various combinations each having a material for the base layer and a material for the surface layer, and respectively pressure-bonded by cold rolling. Thus, double layer pressure-bonded sheets each having a thickness of 0.6mm were provided. The double layer pressure-bonded sheets were maintained at 1050°C in an argon gas atmosphere for three minutes for diffusion annealing, whereby primary clad materials were provided. After the

annealing, the primary clad materials were cold-rolled at a rolling reduction of 75%, and then annealed under the same conditions as in the previous annealing, whereby secondary clad materials were provided. The secondary clad materials each had a total thickness of 0.15mm, and the base layers (Ni layers) and the surface layers (Nb layers or Mo layers) of the respective secondary clad materials each had an average thickness as shown in Table 2.

For comparison, a pure Ni thin plate (Sample No.11 in Table 2) having a thickness of 0.15mm was prepared. This thin plate was cold-rolled, and then maintained at 1050°C in an argon gas atmosphere for three minutes for annealing.

[0042] Next, sputtering test pieces (10mm×10mm) were sampled from the clad materials and the pure metal thin plate of the respective samples, and a removal time required for completely removing each of the 0.15mm thick test pieces by sputtering was measured under the same conditions as in Examples 1. A removal time ratio was determined by dividing the removal time by the time required for removing the pure Ni thin plate by sputtering. The results are also shown in Table 2.

[0043] By utilizing the respective samples, cup-shaped discharge electrodes each having an outer diameter of 1.7mm, an inner diameter of 1.5mm and a tube length of 5mm were produced through a deep drawing process including eight

drawing steps without intermediate annealing as in Examples 1. The interior surfaces of the tubular portions of the resulting products (cup-shaped discharge electrodes) were observed. The results of the observation are also shown in Table 2.

[0044] Table 2

Sample No.	Thickness (μm)			Surface layer thickness ratio (%)	Removal time ratio	Deep drawability	Remarks
	Ni layer	Nb layer	Mo layer				
11	150	-	-	-	1.00	Excellent	Comparative example
12	140	10	-	7	1.07	Base layer exposed	Comparative example
13	140	-	10	7	1.03	Base layer exposed	Comparative example
14	130	-	20	13	1.06	Excellent	Comparative example
15	130	20	-	13	1.14	Excellent	Inventive example
16	90	60	-	40	1.43	Excellent	Inventive example
17	50	100	-	67	1.71	Slight undulations	Inventive example
18	40	110	-	73	1.86	Multiple undulations	Comparative example

[0045] As can be understood from Table 2, the clad materials of Samples No. 15, No. 16 and No. 17 (Inventive Examples) were excellent in removal time ratio with respect to the pure Ni thin plate of Sample No. 11, and the sputtering resistance was improved with an increase in the thickness of the surface layer. Samples No. 15 and No. 16 were excellent in deep drawability. As for Sample No. 17, slight undulations attributable to Luders bands were observed on the interior surface of the tubular portion of the product, but its deep drawing was performed without problems.

The surface layers of the clad materials of Samples No. 12 and No. 13 (Comparative Examples) each had a small thickness (10μm), so that the base layers were partly exposed from the surface layers on the interiors of the products. Sample No. 14 (Comparative Example) was excellent in deep drawability, but the sputtering removal time ratio was much smaller than Sample No. 15 (Inventive Example) which had the same surface layer thickness. Therefore, it was confirmed that Mo was poorer in the sputtering resistance than Nb. Sample No. 18 (Comparative Example) was very poor in deep drawability and a multiplicity of undulations were observed on the interior surface of the tubular portion of the product, because the surface layer thickness was greater than 70% of the total thickness. As a result, a forming punch bit into projections of the undulations,

failing to produce the cup-shaped discharge electrode by the deep drawing.